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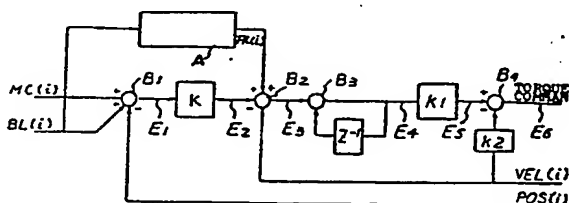
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### NUMERICAL CONTROLLER.

A numerical controller which reliably liberates the positional precision from the effect of static friction and dynamic friction applied as disturbance to the servo loop in the case when a servo system is constructed in the form of a semi-closed loop to numerically control a machine tool driven by a servo motor and to determine its position. The numerical controller has a backlash correction function and supplies the servo system with a backlash correction data (BL(I)) that is distinguished from the ordinary motion command (MC(I)). In response to the backlash correction data (BL(I)), an offset command that corresponds to a friction torque  $F_a$  in the mechanical system is given to the servo system as a torque correction signal (FR(I)).



DESCRIPTION

## NUMERICAL CONTROL APPARATUS

Technical Field

This invention relates to a numerical control  
5 apparatus, which has a backlash correction function for  
a move command, for effectively carrying out  
positioning in a semi-closed loop servo system.

Background Art

A semi-closed loop-type control circuit of the  
10 kind shown in Fig. 3 is employed as a CNC servo-control  
circuit. In the Figure, an information processing  
circuit X comprises a CPU and a memory and forms a  
command signal for a servomotor. A servomechanism Y is  
constituted by a comparator circuit a for comparing the  
15 command signal and a signal from a position detector e,  
a servo drive circuit b, a servomotor c, a velocity  
detector d and a position detector e employing a  
resolver or a pulse encoder, and is adapted to control  
a machine Z such as a table via a ball screw shaft f.

20 As illustrated, the semi-closed loop system  
controls a load by performing position detection at a  
portion of the motor shaft or ball screw shaft in front  
of the machine Z, such as a table, which is the object  
to be finally controlled. Control is performed  
25 accurately up to the motor shaft or ball screw shaft,  
and from this point onward control depends on the  
precision of the machine.

Fig. 4 is a block diagram of such a servo-control

system, in which  $K$  denotes position gain,  $k_1$  and  $k_2$  gains,  $K_T$  a torque constant,  $T_L$  disturbance, and  $J_m$  rotor inertia.

In control of the machine by such a semi-closed  
5 loop system, a response delay due to backlash in the  
mechanical system arises when there is a change in the  
direction of servomotor rotation. In order to improve  
upon this delay with respect to a move command, the  
conventional practice is to supply the servo system  
10 with a backlash correction signal together with the  
move command signal.

Fig. 2 is a block diagram illustrating an example  
of a control circuit in which a backlash correction  
signal  $BL(i)$  of this kind is inputted together with a  
15 move command signal  $MC(i)$  to the servo system to form a  
torque command. In Fig. 2, an integration term  $z^{-1}$  is  
expressed using a  $Z$  conversion (pulse transfer function  
conversion).  $VEL(i)$  indicates a fed back velocity  
signal, and  $POS(i)$  represents an amount of movement in  
20 a sampling period  $T$ , namely a fed back position signal.

In this conventional control circuit, the response  
delay of the servo system is improved by inputting the  
backlash correction signal to the servo system.  
However, since frictional resistance is present in an  
25 actual servomotor and machine, positional displacement  
based on a response delay still remains when the  
servomotor reverses its direction of rotation. If a  
machine tool is to be controlled along, e.g., a

circular arc by controlling a plurality of axes simultaneously, positional displacement caused by frictional resistance in the machine tool will hinder machining along a true circle.

5 Disclosure of the Invention

The present invention has been devised in order to solve the aforementioned problem and its object is to provide a numerical control apparatus capable of improving the positional precision in a semi-closed  
10 loop servo system by forming a torque command that takes frictional resistance into consideration.

In accordance with the present invention, there is provided a numerical control apparatus of a semi-closed loop servo system for controlling a servomotor by  
15 forming a position command by a move command and a backlash correction command for backlash at a mechanical load, comprising: discriminating means for discriminating, on the basis of the backlash correction command, a quadrant position prevailing when the  
20 direction of rotation of the servomotor reverses; correcting means for forming a torque correction signal corresponding to frictional resistance of the mechanical load; and arithmetic means for computing a velocity command decided from the position command by  
25 the torque correction signal.

Accordingly, in the numerical control apparatus of the present invention, a position command regarding the servo system and a backlash correction command are

applied to a comparator to which the servomotor position signal is inputted, and a torque correction signal corresponding to the frictional torque of the machine constituting the load is applied to the servo system as offset data in dependence upon the quadrant position which prevails when the direction in which the servomotor rotates reverses. Thus, accurate positional control is realized by eliminating the influence of friction with regard to the load.

#### 10 Brief Description of the Drawings

Figs. 1(a), (b) are a block diagram and flowchart illustrating the general arrangement of the present invention, Fig. 2 is a block diagram illustrating an example of a circuit according to the prior art, Fig. 3 is a circuit diagram of a servomotor control apparatus using a semi-closed loop system, and Fig. 4 is a block diagram of a servo-control system.

#### Best Mode for Carrying Out the Invention

An embodiment of the present invention will now be described in detail with reference to the drawings.

Fig. 1(a) is a block diagram illustrating the general arrangement of the invention. The move command  $MC(i)$  formed by an information processing circuit and the backlash correction command  $BL(i)$  are inputted to a comparator  $B_1$  of a servo system, and an error signal  $E_1$  is formed by comparing these commands with the amount of movement of a servomotor output shaft in a sampling period  $T$ , namely the position signal  $POS(i)$ . The error

signal  $E_1$  is multiplied by the position gain  $K$  to form a velocity command  $E_2$ , which is applied to a comparator  $B_2$ . Also inputted to the comparator  $B_2$  are the servomotor velocity signal  $VEL(i)$  and a torque correction signal  $FR(i)$  obtained from a correction circuit A by processing the backlash correction command  $BL(i)$  under predetermined conditions.

Fig. 1(b) is a flowchart for forming the torque correction signal  $FR(i)$  in the correction circuit A. Solely the backlash correction command  $BL(i)$  is inputted to the correction circuit A, which outputs the torque correction signal  $FR(i)$  corresponding to frictional resistance in accordance with the quadrant position that prevails when the servomotor reverses direction. More specifically, a frictional resistance value  $F_a$  of the machine coupled to the servomotor is preset, and the following torque correction command  $FR(i)$  is computed in dependence upon the quadrant position, which is discriminated by the backlash command  $BL(i)$ , prevailing when the servomotor reverses direction:

- (1)  $FR(i) = -F_a / (K_1 T)$   
for the third quadrant [ $BL(i) < 0$ ];
- (2)  $FR(i) = 0$   
for  $BL(i) = 0$ ; and
- (3)  $FR(i) = F_a / (K_1 T)$   
for the first quadrant [ $BL(i) > 0$ ].

In accordance with the correction circuit A of the control apparatus constructed as set forth above, the

torque correction signal corresponding to frictional resistance is applied to the comparator  $B_2$  as offset data, and a velocity command  $E_3$  from the comparator  $B_2$  is inputted to a comparator  $B_3$  as a signal which  
5 compensates for frictional resistance. Subsequent processing is the same as in the example of the prior-art circuit of Fig. 2, in which the command signal is corrected by the integration term  $z^{-1}$  and the gains  $k_1$ ,  $k_2$  so that a comparator  $B_4$  may form a torque  
10 command  $E_6$  for the servomotor.

In accordance with the numerical control apparatus of the present invention, as clarified by the description of this embodiment, a backlash correction regarding the move command is carried out in the  
15 semi-closed loop servo system, and a torque correction can be achieved by taking the frictional resistance of the mechanical system into consideration. As a result, there is an improvement in positional displacement based on a response delay at the time of a change in  
20 the rotating direction of the servomotor.

Though an embodiment of the present invention has been described, the invention is not limited thereto but can be modified in various ways without departing from the scope of the claims.

#### 25 Industrial Applicability

The numerical control apparatus of the present invention can be utilized as a semi-closed loop servo-control system adapted to effect a backlash

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correction with regard to a position command.

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## CLAIMS:

1. A numerical control apparatus for controlling a semi-closed loop servo-control system which controls a servomotor by forming a position command by a move  
5 command and a backlash correction command for backlash at a mechanical load, comprising:

discriminating means for discriminating, on the basis of the backlash correction command, a quadrant position prevailing when the direction of rotation of  
10 the servomotor reverses;

correcting means for forming a torque correction signal corresponding to frictional resistance of the mechanical load; and

arithmetic means for computing a velocity command  
15 decided from said position command by the torque correction signal.

2. A numerical control apparatus according to claim 1, characterized in that said correcting means is adapted to store a frictional resistance value of the  
20 mechanical load and form the torque correction signal in accordance with a predetermined offset parameter.

Fig. 1(a)

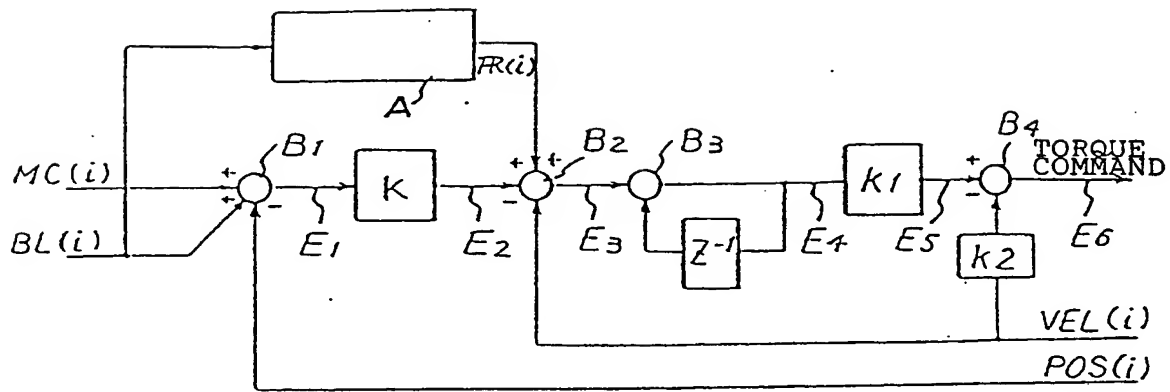


Fig. 1 (b)

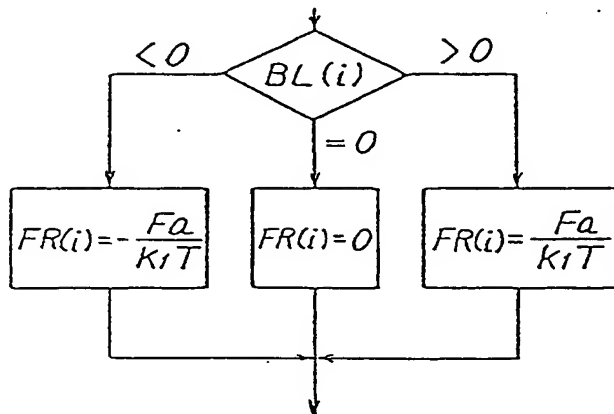


Fig. 2

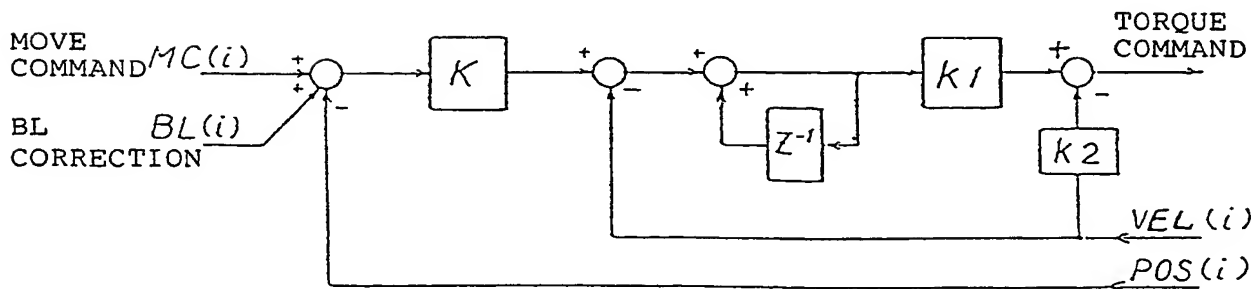


Fig. 3

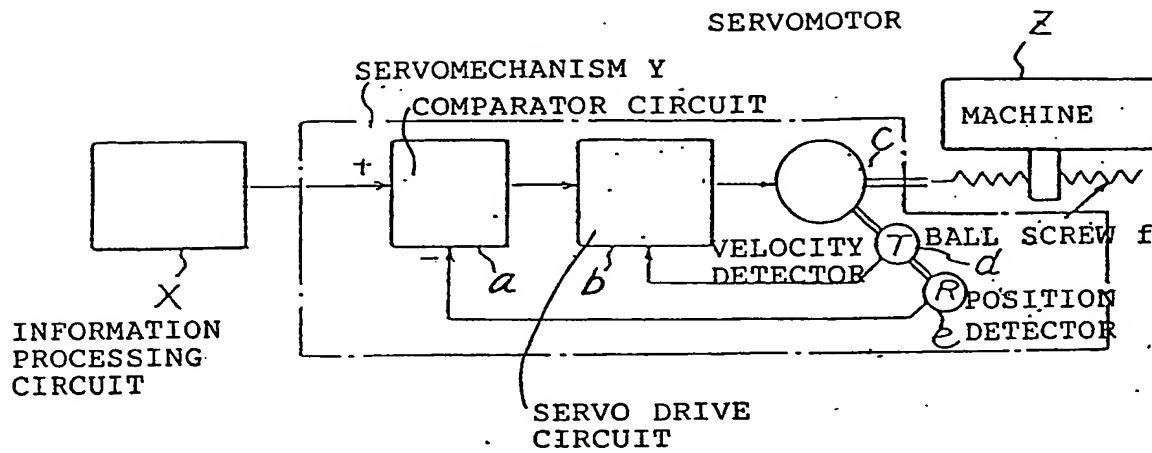
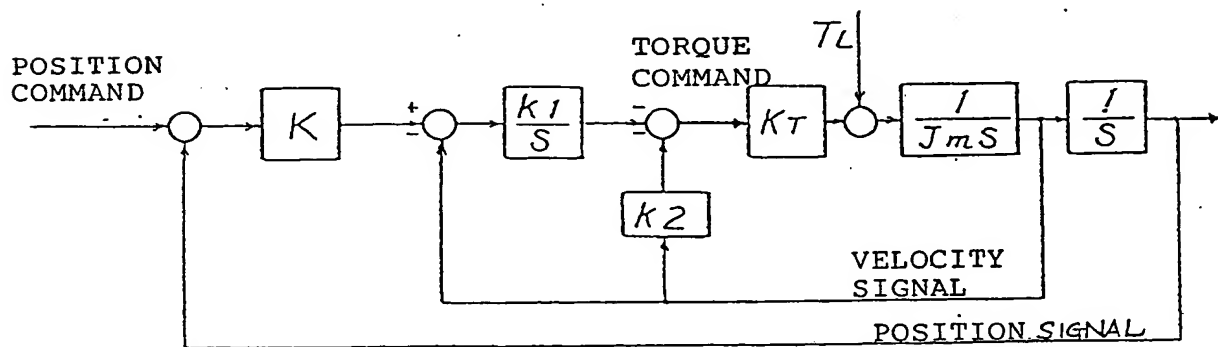


Fig. 4



# INTERNATIONAL SEARCH REPORT

00292574

International Application No

PCT/JP87/00967

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) <sup>3</sup> According to International Patent Classification (IPC) or to both National Classification and IPC <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <span>Int.Cl<sup>4</sup></span> <span>G05D3/12</span> </div>								
<b>II. FIELDS SEARCHED</b> <div style="text-align: center; margin-top: 10px;">Minimum Documentation Searched <sup>4</sup></div> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <tr> <th style="width: 20%;">Classification System</th> <th style="width: 80%;">Classification Symbols</th> </tr> <tr> <td style="text-align: center; padding: 10px;">IPC</td> <td style="padding: 10px;">G05D3/12, G05B19/18</td> </tr> </table> <div style="text-align: center; margin-top: 10px;">Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>5</sup></div> <div style="display: flex; justify-content: space-between; margin-top: 10px;"> <div style="width: 45%;"> <p>Jitsuyo Shinan Koho</p> <p>Kokai Jitsuyo Shinan Koho</p> </div> <div style="width: 50%;"> <p>1971 - 1987</p> <p>1971 - 1987</p> </div> </div>			Classification System	Classification Symbols	IPC	G05D3/12, G05B19/18		
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IPC	G05D3/12, G05B19/18							
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT</b> <sup>14</sup> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <tr> <th style="width: 10%;">Category <sup>6</sup></th> <th style="width: 60%;">Citation of Document, <sup>16</sup> with indication, where appropriate, of the relevant passages <sup>17</sup></th> <th style="width: 30%;">Relevant to Claim No. <sup>18</sup></th> </tr> <tr> <td style="text-align: center; vertical-align: top; padding: 10px;">A</td> <td style="padding: 10px;">           JP, A, 60-116004 (Fanuc Ltd.)            22 June 1985 (22. 06. 85)            Page 2, upper right column to page 3,            upper right column, Fig. 2            (Family: none)         </td> <td style="text-align: center; vertical-align: top; padding: 10px;">1-2</td> </tr> </table>			Category <sup>6</sup>	Citation of Document, <sup>16</sup> with indication, where appropriate, of the relevant passages <sup>17</sup>	Relevant to Claim No. <sup>18</sup>	A	JP, A, 60-116004 (Fanuc Ltd.) 22 June 1985 (22. 06. 85) Page 2, upper right column to page 3, upper right column, Fig. 2 (Family: none)	1-2
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<div style="display: flex; justify-content: space-between;"> <div style="width: 48%;"> <p><sup>19</sup> Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 48%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"Z" document member of the same patent family</p> </div> </div>								
<b>IV. CERTIFICATION</b> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <tr> <td style="width: 50%; padding: 5px;">           Date of the Actual Completion of the International Search <sup>2</sup>  <div style="text-align: center; margin-top: 10px;">February 23, 1988 (23.02.88)</div> </td> <td style="width: 50%; padding: 5px;">           Date of Mailing of this International Search Report <sup>2</sup>  <div style="text-align: center; margin-top: 10px;">March 14, 1988 (14.03.88)</div> </td> </tr> <tr> <td style="width: 50%; padding: 5px;">           International Searching Authority <sup>1</sup>  <div style="text-align: center; margin-top: 10px;">Japanese Patent Office</div> </td> <td style="width: 50%; padding: 5px;">           Signature of Authorized Officer <sup>20</sup> </td> </tr> </table>			Date of the Actual Completion of the International Search <sup>2</sup> <div style="text-align: center; margin-top: 10px;">February 23, 1988 (23.02.88)</div>	Date of Mailing of this International Search Report <sup>2</sup> <div style="text-align: center; margin-top: 10px;">March 14, 1988 (14.03.88)</div>	International Searching Authority <sup>1</sup> <div style="text-align: center; margin-top: 10px;">Japanese Patent Office</div>	Signature of Authorized Officer <sup>20</sup>		
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